

The invention claimed is:

1. A single pass analyzer for detecting the concentration of hydrogen, nitrogen, and oxygen in a sample comprising:

a furnace for fusing a sample;

a supply of carrier gas coupled to said furnace to provide an analyte stream of byproducts of fusion;

conduits defining a flow path for carrying byproducts of fusion in series through a plurality of detector and analyzer elements;

an infrared detector coupled in the flow path for detecting oxygen in the form of CO in said sample;

an infrared detector coupled in the flow path for detecting oxygen in the form of CO<sub>2</sub> in said sample;

a catalyst coupled in the flow path for converting hydrogen in hydrogen compounds to H<sub>2</sub>O and CO to CO<sub>2</sub>;

an infrared detector having an input coupled to said catalyst for detecting hydrogen as H<sub>2</sub>O in the analyte stream from the catalyst;

a detector comprising a high sensitivity CO<sub>2</sub> infrared detector coupled in the flow path for detecting low levels of oxygen in the sample in the form of CO<sub>2</sub>;

a scrubber coupled to said fourth detector, said scrubber operative to remove H<sub>2</sub>O from the analyte stream; and

a thermal conductivity cell coupled to said scrubber for detecting nitrogen in a sample.

2. The analyzer as defined in claim 1 wherein said catalyst is copper oxide operating at about 650°C.

3. The analyzer as defined in claim 2 and further including a flow controller coupled to said conduits.

4. The analyzer as defined in claim 3 and further including a supply of carrier makeup gas coupled between said scrubber and said thermal conductivity cell.

5. A single pass analyzer for detecting the concentration of hydrogen, nitrogen, and oxygen in a sample, said analyzer including a furnace for fusing a sample, and a supply of carrier gas for sweeping an analyte stream including the byproducts of fusion through a plurality of series-coupled elements comprising:

- 5       a first infrared detector for detecting carbon monoxide from said sample;  
          a second infrared detector for detecting the carbon dioxide from said sample;  
          a heated  $\text{CuO}$  catalyst for converting hydrogen compounds to  $\text{H}_2\text{O}$  and  $\text{CO}$  to  $\text{CO}_2$ ;  
          a third infrared detector coupled in series directly downstream of said catalyst for detecting hydrogen compounds as  $\text{H}_2\text{O}$ ;  
          a fourth infrared detector for detecting oxygen in the form of  $\text{CO}_2$ ;  
          a scrubber operative to remove  $\text{H}_2\text{O}$  from the analyte stream; and  
          a thermal conductivity cell for detecting nitrogen in the sample.

6. A method of determining the concentration of hydrogen in a sample in the form of different hydrogen compounds comprising:

          heating a specimen in a fusion furnace at temperatures increasing from room ambient to above about  $1500^\circ\text{C}$ ;

- 5       sweeping the byproducts of fusion in an analyte stream from the furnace; and  
          detecting the hydrogen compounds in the analyte stream as a function of temperature to identify concentrations of specific hydrogen compounds.

7. The method as defined in claim 6 wherein said detecting step includes employing a heated  $\text{CuO}$  catalyst to convert hydrogen compounds in the analyte stream to  $\text{H}_2\text{O}$  and providing an  $\text{H}_2\text{O}$  IR detector immediately downstream of the catalyst to detect hydrogen as a function of detected  $\text{H}_2\text{O}$ .

8. The method as defined in claim 6 wherein said compounds include  $\text{H}_2\text{O}$ ,  $\text{H}_2$ , and metal hydrides.

9. The method as defined in claim 6 wherein said temperature is increased from room ambient temperature to about 2000°C.

10. A hydrogen analyzer comprising:

a fusion furnace for fusing a sample containing hydrogen;

a source of carrier gas for sweeping byproducts of fusion from the furnace in an analyte stream;

5 a heated CuO catalyst coupled to said fusion furnace in the analyte stream for converting hydrogen compounds to H<sub>2</sub>O; and

an H<sub>2</sub>O IR detector coupled to said catalyst immediately downstream of the stream of analyte from said catalyst for detecting hydrogen in a sample.

11. The analyzer as defined in claim 10 wherein said CuO catalyst is heated to about 650°C to convert hydrogen compounds to gaseous H<sub>2</sub>O.

12. The analyzer as defined in claim 11 and including a furnace control for increasing the temperature of said furnace from room ambient to about at least 1500°C to speciate hydrogen, nitrogen, and oxygen compounds simultaneously.

13. A method of determining the concentration of hydrogen in a sample in the form of different hydrogen compounds comprising:

heating a specimen in a fusion furnace at temperatures increasing from room ambient to above about 1500°C;

5 sweeping the byproducts of fusion in an analyte stream from the furnace;

detecting the hydrogen compounds in the analyte stream as a function of temperature to identify concentrations of specific hydrogen compounds by employing a heated CuO catalyst to convert hydrogen compounds in the analyte stream to H<sub>2</sub>O and providing an H<sub>2</sub>O IR detector immediately downstream of the catalyst to detect hydrogen as a function of detected H<sub>2</sub>O;

10 calculating the effect of CO<sub>2</sub> on the level of hydrogen measured by the H<sub>2</sub>O IR detector; and

compensating the measured hydrogen level based upon the calculating step.

14. The method as defined in claim 13 wherein said compensating step is performed by a microprocessor using a look-up table of correction factors.

15. An analyzer for determining the concentration of hydrogen in a sample in the form of different hydrogen compounds comprising:

a fusion furnace for fusing a sample;

a supply of carrier gas coupled to said furnace for sweeping the byproducts of fusion in an analyte stream from the furnace;

a  $\text{CuO}$  catalyst to convert hydrogen compounds in the analyte stream to  $\text{H}_2\text{O}$ ;

an  $\text{H}_2\text{O}$  IR detector immediately downstream of said catalyst to detect hydrogen as a function of detected  $\text{H}_2\text{O}$ ; and

a microprocessor for calculating the effect of  $\text{CO}_2$  on the level of hydrogen measured by the  $\text{H}_2\text{O}$  IR detector and compensating the measured hydrogen level based upon the calculating step.

16. The analyzer as defined in claim 15 and further including:

a detector for detecting oxygen as carbon monoxide in said sample;

at least one infrared detector for detecting oxygen as carbon dioxide in said sample;

a scrubber operative to remove  $\text{H}_2\text{O}$  from the analyte stream; and

a thermal conductivity cell for detecting nitrogen in the sample.

17. A single pass analyzer for determining the concentration of hydrogen, nitrogen, and oxygen in a sample comprising:

a furnace for fusing a sample;

a supply of carrier gas coupled to said furnace to provide an analyte stream of byproducts of fusion;

conduits defining a flow path for carrying byproducts of fusion in series through a plurality of detector and analyzer elements;

a first infrared detector coupled in the flow path for detecting oxygen in the form of  $\text{CO}$  in said sample;

10 a second infrared detector coupled in the flow path for detecting oxygen in the form of CO<sub>2</sub> in said sample;

a catalyst coupled in the flow path for converting hydrogen in hydrogen compounds to H<sub>2</sub>O and CO to CO<sub>2</sub>;

15 a third infrared detector having an input coupled to said catalyst for detecting hydrogen as H<sub>2</sub>O in the analyte stream from the catalyst;

a fourth detector comprising a high sensitivity CO<sub>2</sub> infrared detector coupled in the flow path for detecting low levels of oxygen in the sample in the form of CO<sub>2</sub>;

a scrubber coupled to said fourth detector, said scrubber operative to remove H<sub>2</sub>O from the analyte stream;

20 a thermal conductivity cell coupled to said scrubber for detecting nitrogen in a sample; and

a microprocessor coupled to each of said detectors and to said thermal conductivity cell for simultaneously calculating the hydrogen, nitrogen, and oxygen concentrations in a sample.

18. The analyzer as defined in claim 17 and further including a display coupled to said microprocessor for displaying the calculated concentrations.

19. The analyzer as defined in claim 18 and further including a printer for printing the calculated concentrations.

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